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UNITED STATES PATENT APPLICATION FOR:

DHCP over Mobile IP

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TITLE OF THE INVENTION

DHCP over Mobile IP

CROSS-REFERENCE TO RELATED APPLICATIONS.

This application claims the benefit of U.S. Provisional Application No. 60/286,425 filed April 25, 2001, incorporated herein by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT.

Not applicable.

REFERENCE TO A "MICROFICHE APPENDIX."

Not applicable.

BACKGROUND OF THE INVENTION

(1) FIELD OF THE INVENTION.

The present invention is directed to mobile communications, more particularly to mobile Internet communications.

(2) DESCRIPTION OF THE RELATED ART

The Internet Protocol ("IP" or "TCP/IP") has become the de facto standard for most network communication. The earliest networks required all the devices be connected to each other by wired connections, and the device needed an IP address that uniquely identified the device's point of attachment to the Internet. The device was required to be located on the network indicated by its IP address in order to receive datagrams destined to it; otherwise, datagrams destined to the device would be undeliverable. For a device to change its point of

attachment without losing its ability to communicate, the device either had to change its IP address whenever it changed its point of attachment, or host-specific routes had to be propagated throughout much of the Internet routing fabric. Furthermore, because IP unlike other networking protocols such as IPX, needs addresses and configuration settings to be defined on each device on the network, there may be an immense amount of system administration work.

The Dynamic Host Configuration Protocol ("DHCP") was developed to ease the amount of work and administration required to manage IP networks. DHCP allowed "pools" of TCP/IP addresses to be assigned to a DHCP server which are then allocated to client devices by the DHCP server. The pools are called scopes in DHCP terminology. Furthermore, DHCP not only assigned TCP/IP addresses, but also enabled required configuration settings such as subnet, mask, default router, and DNS server which are required for TCP/IP to work properly to be set. DHCP works across most routers and allocates IP addresses according to the subnet where the request initiated, eliminating the need to re-configure a device that moved from one subnet to another. Another feature of DHCP is that addresses can be leased for periods of time. When the address expires, the device may either request a renewal, otherwise, the IP address is put back into the pool of unallocated addresses which helps to recover unused IP addresses.

The procedure for using DHCP is quite simple. When a DHCP client is first switched on, it sends a broadcast packet on the network with a DHCP request. This is picked up by a DHCP server, which allocates an IP address to the device from one of the scopes (the pools of addresses) it has available.

Each DHCP scope is used for a different TCP/IP network segment. On networks with routers that support DHCP, extra information is added to the request by the router to tell the server which network the request came from. The DHCP server uses this information to pick an address from the correct scope. The server replies to the client, allocating it the TCP/IP address and settings required.

However, DHCP doesn't allocate the address permanently. It tells the client that it has "leased" the address to it for a specific time period, which the administrator can control. By default DHCP is installed with a three-day lease period. When the lease expires, the client can

ask the server to renew the lease. If the DHCP server doesn't hear from the client beyond the expiration of the lease period, it will put that address back in the pool ready to be re-used.

Recently, mobile, usually wireless, devices have gained popularity. It is desired that these devices also use the IP protocol. Because mobile devices change locations, the device may be located on either its home or a foreign network. Presently, each mobile device is always identified by its home address, regardless of its current point of attachment to the Internet. A standard protocol, Mobile IP, is used to forward IP packets between a mobile host on a foreign network and the home network for the mobile host. While situated away from its home network, a mobile device is associated with a care-of address, which provides information about its current point of attachment to the Internet.

A mobile host that boots on its home subnet can use DHCP to obtain a home IP address on its home subnet. By default, a DHCP server will allocate an IP address for the subnet where a DHCP request originates. Therefore, a mobile host that boots on a foreign subnet cannot simply broadcast a DHCP request on the local subnet to obtain an IP address for its home subnet. Standard Mobile IP requires that a mobile host must have a permanent IP address for its home subnet. Therefore, a mobile host, without an IP address, cannot use Mobile IP to forward a DHCP request to a DHCP server on its home subnet because it does not have a home IP address. Therefore, a mobile device cannot use DHCP when booting on a foreign network. Thus, the need exists for a mobile host to be able to access a DHCP server on its home network from a foreign network to obtain its home address.

In one proposed solution a mobile host can send a Mobile IP Registration Request, with a "home address" of zero to a "home agent" on its home subnet, obtain a "temporary home IP address" from the home agent and then send inbound requests to the home DHCP server, therefore the home DHCP server services the request. The solution assumes that the corresponding DHCP Reply will be sent to a broadcast MAC address (i.e. Ethernet address). However, the DHCP standard recommends that a DHCP reply be sent to a unicast MAC address. A Mobile IP home agent in a router can only receive frames with the unicast destination 802 address of the router interface. Therefore, a DHCP Reply with a unicast 802 destination address cannot be forwarded to the mobile host by the home agent.

A proposed solution for the previous problem has been to enter the temporary IP address assigned to the mobile host into the giaddr field of a DHCP request. However, this proposal is in conflict with current DHCP/BOOTP forwarding rules. BOOTP rules require that when a BOOTP relay agent receives a request, if the giaddr field is zero, the BOOTP relay agent inserts its address and then forwards the request; however, if the giaddr field is nonzero, the BOOTP relay agent cannot forward the request. Therefore, this proposed solution will not work because the BOOTP relay agent cannot forward a BOOTP or DHCP request with a nonzero giaddr field.

Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention.

BRIEF SUMMARY OF THE INVENTION

In view of the aforementioned needs, one aspect of the invention contemplates coupling a BOOTP relay agent to a mobile host ("MH") Mobile IP home agent. The MAC address of a MH is used as the Mobile IP MH identifier. As those skilled in the art can readily appreciate, for 802 networks, the 802 address, which is a specific type of MAC address, is used. The MAC or 802 address is inserted in a Mobile Host Identifier Extension in Mobile IP Registration Requests. The existing DHCP standard requires that the MAC address is also inserted into the chaddr field of the DHCP request and reply messages. The chaddr field in a DHCP reply is used to identify the MH on a foreign subnet so that Mobile IP can be used to forward the DHCP reply, with the IP address allocated by the DHCP server, to the MH. This requires that a home subnet and any foreign subnets are 802 LANS and that a mobile host is an 802 (i.e. 802.11) station.

The present invention does not require changes to existing legacy IP stacks or existing DHCP and BOOTP servers. As a result, proxy mobile host software can transparently provide seamless IP subnet mobility for existing legacy IP hosts that use DHCP or BOOTP to obtain an IP address, and other configuration parameters from existing DHCP/BOOTP servers.

The present invention encapsulates outbound broadcast and multicast IP packets destined to a mobile host with a foreign agent care-of address. Inner and outer encapsulation

headers are used to forward DHCP messages from a DHCP server outbound through a forward tunnel to a mobile host on a foreign subnet and are also used to forward DHCP messages from a mobile host on a foreign subnet inbound through a reverse tunnel to the home subnet.

5 In the present invention, a mobile host provides the entry point for a DHCP reverse tunnel. A mobile host on a foreign subnet must filter transmitted packets to automatically detect DHCP packets. A BOOTP relay entity provides the entry point for a DHCP forward tunnel.

10 A MH must add an inner encapsulation header to inbound DHCP IP packets. The source IP address in the inner encapsulation header is set to 0 to indicate that the packet is from a MH that does not have a registered home IP address. The "BOOTP relay" entity coupled to a Mobile IP Home Agent ("HA") must add an inner encapsulation header to outbound DHCP IP packets. The destination address in the inner encapsulation header is set to 0 to indicate that the packet is destined to a MH that does not have a registered IP address.

15 Outer encapsulation headers contain the HA address and the care-of address (i.e. Mobile IP Foreign Agent ("FA") address) for the MH.

20 In the present invention, the HA and FA use the MAC or IEEE 802 address ("802 address") of a MH to associate DHCP messages with the mobility bindings for a MH without a registered home IP address. The 802 address is obtained from the source 802 address in frames sent from the MH to a FA. Otherwise, the 802 address is obtained from the 'chaddr' field in DHCP request and reply (i.e. BOOTREQUEST and BOOTREPLY) messages.

A MH can, optionally, include the Network Access Identifier (NAI) extension in Mobile IP Registration requests. Either the NAI or the MH's 802 address can be used to locate administration and authentication information for the MH.

25 A Mobile IP Mobile Host Identifier ("MHID") Extension is used to flexibly extend the identifier naming space for Mobile IP Mobile Hosts. It is defined consistently with the Endpoint Discriminator option for Multilink PPP (RFC 1990).

30 Among those benefits and improvements that have been disclosed, other objects and advantages of this invention will become apparent from the following description taken in conjunction with the accompanying drawings. The drawings constitute a part of this

specification and include exemplary embodiments of the present invention and illustrate various objects and features thereof.

(G) BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The drawings illustrate the best mode presently contemplated of carrying out the invention.

This the drawings:

FIG 1 is a block diagram illustrating how encapsulation headers are added and removed at each entity on the path between a DHCP client and a DHCP server;

FIG 2A is a detailed block diagram showing the steps involved in the initiating of a DHCP request and its subsequent receipt by a foreign agent and subsequent forwarding to the mobile hosts home agent;

FIG 2B is a detailed block diagram showing the steps utilized by the home agent upon receipt of the DHCP request from the foreign agent;

FIG 2C is a detailed block diagram showing the steps utilized by a DHCP server upon receipt of the DHCP request, and subsequent forwarding of the reply to the home agent; and,

FIG 2D is a detailed block diagram describing the steps from when the foreign agent receives the DHCP until it is finally received and processed by the mobile host .

(H) DETAILED DESCRIPTION OF INVENTION

A detailed description of the best mode and preferred embodiment contemplated for the present invention will now be given.

Referring now in particular to FIG 1 is shown how encapsulation headers are added and removed at each entity on the path between a DHCP client 131 and a DHCP server 141 when the client makes a request from a foreign network. A more detailed description of the actual steps are described in Figure 2. Figure 1 assumes that the mobile host is connecting to a foreign subnet and the DHCP server 141 and BootP relay entity 139 reside on a home 802 subnet. Portions of the packet that are not used by an entity are shown in dashed lines. For example the mobile host may use proxy mobile host software which only uses the DHCP request Host IP header 107 in generating the encapsulated IP packet while the foreign agent must look at the BOOTP header 103 to obtain the mobile host's 802 address.

The DHCP client in an IP host 131 within the mobile host 133 generates the DHCP request. The packet for the request includes the DHCP Configuration parameters 101, the

BOOTP header 103, the UDP header 105 and the Host IP header 107. The mobile host's 133 software may be integrated with the DHCP client's 131 IP stack or proxy software may exist as an independent entity. The mobile 133 host then adds an IP-in-IP encapsulation header 109. The FA 135 address is the destination address and the source IP address is 0 in the IP-in-IP encapsulation header 109.

The packet from the mobile host is then sent to the foreign agent 135 across path 121. The foreign agent 135 then adds an outer encapsulated IP header 111 to the packet and then forwards the packet to the home address 137 across path 123. The HA 137 upon receiving the encapsulated DHCP request through the reverse IP tunnel then removed the Outer Encapsulated IP header 111. The packet is then forwarded by the HA 137 to a BootP relay entity 139 connected to the HA 137. The BootP relay entity 139 then removes the Inner encapsulated IP header 109 and then forwards the DHCP request via path 125 to the DHCP Server 141.

The DHCP server 141 then sends the reply to the BootP relay entity 139 over path 125. When the BootP relay entity 139 receives the reply, it adds an inner encapsulated IP header with the source address set equal to the home agent address and the destination address set to zero. The BootP relay entity 139 then forwards the reply to the home agent which then adds an outer IP-in-IP encapsulation header 111 with the source address set to the home agent and the destination address set to the foreign agent care-of address. The packet is then forwarded to the foreign agent 135 across path 123. The foreign agent 135 then removes the outer encapsulated IP header 111 and forwards the packet to the mobile host 133. The mobile host 133 upon receiving the packet removes the inner encapsulated IP header 109 and forwards the packet to the DHCP client 131.

Referring now to Figure 2A, the process starts at step 201 when a DHCP client 131 generates a DHCP request packet. At step 203 the mobile host determines whether the mobile host is on a home network or a foreign subnet. If at step 203 it is determined that the mobile unit is on its home subnet, then processing branches to the normal DHCP routine at step 205. If the mobile host determines it is connected to a foreign agent, the mobile host adds an IP-in-IP encapsulation header 109 to the DHCP IP packet at step 207. The mobile host 133 then sets the destination address of the IP-in-IP encapsulation header 109 to the FA's 135 address

and the source IP address is set to 0. The packet's giaddr field is also set to zero. At step 209 the MH 133 sends the packet to the FA 135 using the FA's 135 unicast 802 address.

The FA 135 receives the packet in step 211. At step 213 the FA 135 examines the source IP address. If the source IP address is zero then the foreign associate aborts the DHCP process as shown in step 215. The foreign agent 135 determines mobility bindings for the mobile host 133 using IP. If the source IP address is zero, then the FA uses the 802 address of the mobile host to locate mobility bindings for the mobile host 133 as shown in step 217.

At step 219 the FA adds a second, outer IP-in-IP encapsulation header 111 with the destination address set to the unicast HA IP address and the source address set to the FA IP address. The packet is then forwarded to the HA as shown in step 221..

As shown in Figure 2B, the HA 137 receives the DHCP request through reverse IP tunnel as shown in block 223. The HA then removes the outer IP-in-IP encapsulation header from the DHCP request as shown in step 225. Then in step 227 the HA examines the IP address of the inner encapsulation header 109. If at step 229 it is determined that the Source IP address of the inner encapsulation header 109 is not zero, then at step 231 the process aborts. Otherwise, if the source IP address of the inner encapsulation header 109 is zero at step 229, the BOOTP relay entity 139 then obtains the 802 address of the mobile host from the chaddr field in the BOOTP header 103 as shown in step 233

At step 235, the HA forwards the request to a BOOTP relay entity 139 that is coupled to the HA 137.. At step 237, the BOOTP relay entity 139 then inserts the HA address for the home subnet into the giaddr field of the DHCP/BOOTP header 103 and then, at step 237, forwards the request to the DHCP/BOOTP server 141 address

Referring now to figure 2C, at step 243 the DHCP server 141 receives the request. The DHCP sends the reply to the giaddr address in the UDP BOOTPS protocol port 105 at step 245. At step 247, the BOOTP relay entity coupled to the HA receives the DHCP server reply. The BOOTP relay entity 139 then adds the unicast or broadcast destination IP address to the IP header of the reply at step 249. In step 251 the BOOTP relay entity 139 then adds an inner IP-in-IP encapsulation header 109 to the reply, setting the source address to the HA 137 and the destination address is set to 0. A step 253 the BOOTP relay entity 139 sends the reply to the HA 137.

As shown in step 255 the HA 137 examines the destination address of the inner IP-in-IP encapsulation header 109. If the destination header is zero then the HA obtains the 802 address from the chaddr field in the DHCP/BOOTP header 103 as shown at step 257, and then locates the mobility bindings for the mobile host 133 using the 802 standard as shown in step 259. If the destination address of the inner IP-in-IP encapsulation header 109 is nonzero then the mobility bindings are located using the IP address as shown in step 261. The HA 137 then adds an outer IP-in-IP encapsulation header 111 with the source address set to the HA's address and the destination set to the FA care-of-address as shown in step 263. At step 265 the HA then sends the encapsulated DHCP reply to the FA 135.

Referring now to figure 2D, the FA 135 receives the encapsulated DHCP reply through the forward IP tunnel at step 267. The FA 135 then removes the outer IP-in-IP encapsulation header 111 from the reply as shown in step 269. At step 271 the FA 135 examines the IP destination address of the Inner IP-in-IP encapsulation header 109 to determine where to find the mobility bindings for the mobile host 133. If at step 271 the Destination IP Address is nonzero, then processing proceeds to step 273 where normal IP is used to obtain mobility bindings. If the destination IP address is zero at step 271, then the FA 135 must obtain the 802 address for the MH 133 from the chaddr field in the BOOTP reply message as shown in step 275. At step 277 the FA 135 locates the mobility bindings using the 802 address. After obtaining the mobility bindings, the FA 135 forwards the DHCP reply to the 802 address of the MH 133 with the inner IP-in-IP encapsulation header 109 as shown in step 279.

At step 281, the MH 133 then removes the inner IP-in-IP encapsulation header 109 and the resulting IP packet is sent to the host IP protocol stack. At step 283, the DHCP reply is then forwarded to the UDP BOOTPC "service access point" (not shown) of the DHCP client in an IP host 131.

The tunneling logic for a MH 133 with a co-located care-of address is similar, except that the inner encapsulation header 109 is optional for outbound packets. Inbound packets must have an inner 109 and outer 111 encapsulation header with a FA 135 care-of address.

The present invention contemplates that the HA and FA use the 802 address of a MH to associate DHCP messages with the mobility bindings for a MH without a registered home

IP address. The 802 address is obtained from the source 802 address in frames sent from the MH to a FA. Otherwise, the 802 address is obtained from the 'chaddr' field in DHCP request or reply.

A MH can optionally include the Network Access Identifier ("NAI") extension in Mobile IP Registration requests. Either the NAI or the MH's 802 address can be used to locate administration and authentication information for the MH.

A Mobile Host Identifier ("MHID") extension is used to flexibly extend the identifier naming space for Mobile IP Mobile Hosts. It is defined consistently with the Endpoint Discriminator option for Multilink PPP (RFC 1990).

A MHID contains a 'Class' field and an 'Address' field.

The Address field contains a unique identifier for a Mobile Host (MH). The identifier should be globally unique. The identifier must be unique within the context of a Mobile IP "domain". The identifier size is determined from the extension Length field. The identifier size may be fixed or variable, depending on the identifier class. A MHID extension is invalid if the Length field indicates a size below the minimum for the class.

The Class field is one octet and indicates the identifier address space. Valid values for the Mobile IP MHID Extension are listed below:

- | | |
|----|--|
| 0 | Null Class |
| 1 | 2-bit Internet Protocol version 4 (Ipv4) Address |
| 3 | 48-bit IEEE 802 Globally Assigned MAC Address |
| 5 | Public Switched Network Directory Number |
| 10 | Network Access Identifier (NAI) |

The MHID extension provides a flexible mechanism for establishing one or more MH identifiers. A MHID may be used for various purposes. For example, an "NAI" identifier may be used to locate administration or authentication records in a database. A "MAC address" identifier may be used to dynamically associate a MH IP address with a MAC address. A MHID may also be used to locate mobility bindings for a MH that does not have a "home IP address".

A MH may include 0 or more MHID extensions in Mobile IP Registration Requests. MHID extensions must appear in a Registration Request before both the Mobile-Home Authentication extension and Mobile-Foreign Authentication extension, if present.

A Mobile IP home or foreign agent must return a MHID extension in a Mobile IP Registration response to acknowledge support for the MHID class. A HA must enter a MHID extension in a Registration Response before the Mobile-Home Authentication extension. A HA must enter a MHID extension in a Registration Response before the Mobile-Foreign Authentication extension, if present.

A MH without a home IP address may set the “home address” field to 0 in a Registration request that contains a MHID extension with an 802 address. A MH that sends such a request must continue to include the 802 address MHID extension in any successive Registration requests (i.e. even if it obtains a home IP address). A HA or FA that accepts a Registration request with an 802 address MHID extension must establish the MH 802

The present invention requires that a MH must send Registration requests with a new Mobile Host Identifier extension that contains the IEEE 802 address of the MH, to establish mobility bindings. A HA or FA that receives a MHID, in a Registration request, with the 802 address of a MH, must create or update mobility bindings for the MH that are indexed by the 802 address. Both the HA and FA must enter a MHID extension in a Registration response, with the 802 address of the MH, to acknowledge that it has created such bindings. MHID extensions are protected by Authentication extensions.

A MH without a home IP address must send Registration requests with the “home address” field set to 0 in a request that contains a MHID extension with an 802 address. A MH that sends such a request must continue to include the 802 address MHID extension in any successive Registration requests, even if it obtains a home IP address. A HA or FA that accepts a Registration request with an 802 address MHID extension must establish the MH 802 address as an index into MH mobility bindings. A HA or FA that accepts a Registration request with both a non-zero home IP address in the “home address” field and an 802 address MHID extension must establish both the MH 802 address and the MH home address as an index into MH mobility bindings.

A FA may include an ICMP MHID extension in FA advertisements to advertise general support for the MHID extension. The Class field should be set to Null or 0.

A DHCP server may assign an IP address with a temporary “lease”; therefore, a MH may lose its home IP address. A MH that has dynamically acquired a “temporary” home IP address, via BOOTP or DHCP, must continue to send Registration requests that include a MHID extension, with its 802 address. The Registration request should also include a MHID extension with the temporary home IP address of the MH. The IP address MHID indicates that the MH is using a temporary address. A HA or FA that receives a Registration request with an 802 address MHID extension and a non-zero “home address” field must maintain mobility bindings that are indexed by both the 802 address and the home IP address.

A MH, on a foreign subnet, must generate a new Registration request whenever it initially acquires a home IP address or whenever its home IP address changes. Any new IP address must be entered into the “home address” field in the request header. The “old” IP address must be entered in a MHID extension in the Registration request until the MH receives a matching Registration response. A HA and FA must examine both the “home address” field and the MHID address. If the “home address” is different than the MHID IP address, then it is assumed that the MHID IP address is “old”. The HA and FA must immediately delete its mobility bindings for the old address.

A “promiscuous HA” can receive frames, that originate on the home subnet, with any unicast 802 destination address. A “non-promiscuous HA” can only receive unicast frames with the 802 destination address for the HA home subnet interface. It is assumed that a HA is “non-promiscuous”.

A DHCP server may transmit “broadcast DHCP reply messages”, with broadcast destination IP and 802 addresses, or “unicast DHCP reply messages” with unicast destination IP and 802 addresses. A unicast destination IP address in a DHCP reply message, for a MH, may not be a “registered” home IP address. A non-promiscuous HA cannot receive such unicast DHCP reply messages. To solve the problem, a “BOOTP relay” software entity is coupled with the Mobile IP software in a non-promiscuous HA. The BOOTP relay entity functions much like a standard BOOTP Relay agent, as defined in the Bootstrap Protocol and RFC 1542. The BOOTP relay entity sets the ‘giaddr’ field, in DHCP request messages from

MHs, to the HA IP address for the home subnet, so that DHCP reply messages are sent to the unicast IP address and unicast 802 address of the HA.

In a promiscuous HA, a "BOOTP reply filter" can replace a BOOTP relay entity. The BOOTP reply filter functions much like a BOOTP relay entity in a non-promiscuous HA, with one notable exception. A BOOTP reply filter does not modify the 'giaddr' field in DHCP requests. Instead, the BOOTP reply filter must promiscuously receive DHCP replies that are destined for MHs on foreign subnets.]

The "BOOTP relay entity" coupled to the HA should generate several proxy test ARP request packets when it receives a DHCPOFFER message from a DHCP server. The target IP address in the test ARP request packets is set to the "offered" IP address. If the BOOTP relay entity receives an ARP response packet, then it should not forward the DHCPOFFER message to the MH. Note that the address may already be in use or the MH may have roamed back to its home subnet.

The maximum transmission unit (MTU) size may be exceeded when an encapsulation header is added to a packet. Therefore, packets may be fragmented and reassembled. The fragmentation and reassembly logic for home and foreign agents is unaffected by the present invention.

The source IP address in the inner and outer encapsulation headers in outbound packets sent from the HA to the MH care-of address both contain the HA IP address; therefore, the BOOTP relay entity and the HA must share a "global" counter that is used for the IDENTIFICATION value in the IP headers.

The BOOTP relay entity coupled to the HA will receive encapsulated packets from multiple MHs all with a source IP address of 0. Therefore, the BOOTP relay entity must maintain reassembly queues that are indexed by the MH 802 address.

The present invention does not require any changes to the BOOTP/DHCP standards,. However, an implementation of the present invention should observe the following rules: (1) a DHCP server should not consider it an error if a DHCP receives a request on its physical subnet and the 'giaddr' address is on the same physical subnet; and (2) a BOOTP relay agent should forward a DHCP request independently of the value in the 'giaddr' field (BOOTP standards prohibits a BOOTP relay agent from modifying a non-zero 'giaddr' value).

Although the invention has been shown and described with respect to a certain preferred embodiment, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification. The present invention includes all such equivalent alterations and modifications and is limited only by the scope of the following claims.